COR-2620
COPY 2 OF 6

ENGINEER TEST PLAN

for

GAMMA I RECTIFYING PRINTER

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I SCOPE

This plan defines the tests and procedures for evaluating the operational, photographic, and rectification capabilities of the GAMMA I RECTIFYING PRINTER.

II BACKGROUND

2.1 Origin of Concept

The program which has culminated in the delivery of the Gamma I instruments, originated in a proposal submitted by [redacted] for the design and development of equipment to rectify the imagery of tipped aerial panoramic photography. STAT

STAT The proposal stemmed in part from [redacted] analysis of customer requirements coupled with detailed experience in the development of panoramic rectifiers.

Experience has shown that in tipped panoramic photography the following types of distortion are encountered:

2.1.1 Panoramic Distortion

The displacement of images from their true, or expected, geometric position due to the geometry of the focal plane and the scanning action of the lens.

2.1.2 Convergent Tip Distortion

The displacement of images from their true, or expected, geometric position due to the introduction of a tipped optical axis in the line-of-flight. This distortion is in addition to, and modifies the position of, points due to panoramic distortion.

2.1.3 Roll Distortion

The displacement of images from their true, or expected, geometric position due to roll of the camera about an axis parallel to the line-of-flight. This distortion is in addition to, and modifies the position of, points due to panoramic and convergent tip distortion.

2.1.4 Scan Positional Distortion

The displacement of images from their true, or expected, geometric position due to the forward displacement of the vehicle during the scan period of the lens. This distortion is in addition to, and modifies the position of, points due to panoramic, convergent tip, and roll distortions.

2.1.5 IMC Distortion

The displacement of images from their true, or expected, geometric position due to the lens motion used to compensate for image motion during the exposure period. This distortion is in addition to, and modifies the position of, points due to panoramic, convergent tip, roll, and scan positional distortions.

2.1.6 Distortion Removal

In the Gamma I instrument, panoramic, convergent tip, and roll distortions are removed during the copying operation.

Scan positional and IMC distortions (which appear as a residual centerline curvature that is the algebraic sum of the two) are not considered. This is because the V/H ratio of the taking system is such that the aforementioned distortion is not of sufficient magnitude to affect the results significantly.

2.2 Development of the Equipment

The development of the Gamma I Rectifying Printer was initiated as the second stage of a two part classified program.

The first stage was a six (6) week design study that was submitted for approval on 17 August 1962, entitled Design Study - Gamma I and II Printers.

The program was temporarily halted by the contracting agency until March 1963, and design specifications were forwarded to the contracting agency on 10 April 1963.

The contract was awarded in June 1963.

2.3 Equipment Description

The Gamma I Rectifying Printer is a compact integral unit that transforms and rectifies distorted scale panoramic photography into enlarged, uniform scale, positive prints suitable for map and chart compilation and revision.

The prints are of normal photographic quality and exhibit no defects with respect to content, density, resolution nor general acceptability for photographic projection printing.

The printer is designed to duplicate proportionally the physical and dynamic aspects of the taking system, but in a reverse manner, i.e., the light source sweeps peripherally about the panoramic film plane, projecting an image through the lens onto the printing easel. The easel, which simulates the earth in map scale, is curved to a cylindrical shape whose radius may be varied to simulate the apparent change in earth curvature as a function of altitude and camera tip angle. The easel may be inclined, with respect to the input film plane, to simulate a tipped taking condition.

The panoramic film nadir may be centered on the rectifier's geometric centerline to compensate for roll in the taking system.

The printer input material is 500 foot spools of 70mm wide processed film containing negative panoramic imagery.

The printer output material is 500 foot spools of 9 1/2 inch wide, type 5427, AERO-Dup film that has been exposed with rectified positive images of the input material during operation.

2.3.1 Light Source

The light source is comprised of a projection lamp, condensers, interference filters, and a cooling fan, all mounted on a rotating scan arm that sweeps along the curved negative stage to expose the film progressively.

A unique varied velocity drive mechanism compensates for the light fall-off, caused by the constantly varying long conjugate dimension, to produce a uniform light/time product at all points along the copy plane.

2.3.2 Negative Stage

The negative stage is comprised of a film platen, a film transport system, and a nadir offset device (roll compensation).

The platen consists of a curved set of tracks that approximate the dimensions and configuration of the camera film plane. The tracks support the edges of the film in such a manner that the light beam can be projected through the film onto the lens.

The film transport is a manually controlled mechanism that mounts the film onto the instrument and allows the operator to translate film from a supply spool, along the platen, and onto a take-up spool. A constant tension device precludes sagging or buckling of the film.

The nadir offset device consists of a scale and an adjustable pointer mounted parallel to the platen tracks. This device serves to indicate the correct location for the film format nadir fiducial mark in terms of camera/vehicle roll.

2.3.3 Lens

The projection lens has been designed and fabricated by [redacted] to STAT
meet the specific requirements of the Gamma I instrument.

It is mounted so that it is driven through its exposure scan arc by the light source drive at a differential velocity that maintains sharp focus at the easel.

The mounting assembly has gimbal type suspension components that allow adjustment of the Scheimpflug angle to operate with the focusing cam to compensate for the variations in projection distance induced by the adjustable tip and position of the copy easel.

2.3.4 Positive (Copy) Stage

The positive stage is comprised of a curved easel and a film transport system.

The easel has manually variable curvature and may be tilted about and translated along, the centerline of the optical path. Its surface is grooved and coupled to a vacuum system so that differential pressure over its surface holds the film tightly to the established cylindrical configuration during exposure.

The film transport system is a mechanized, uni-directional drive that releases the vacuum pressure and drives the copy film a metered distance, automatically, after the completion of each photographic exposure.

2.4 Equipment Configuration

The Gamma I Rectifying Printer is constructed of a two section welded aluminum alloy framework. The two sections are solidly fastened together to form a single rigid unit. All components and mechanisms are fastened to the framework at their respective locations.

The general configuration of the instrument is such that the optical path is folded at an acute angle. This puts the light source (when centered on the platen) and the center of the negative plane at about the eye level of a standing operator.

The negative platen is roughly perpendicular (in a left-right orientation) to the operator's line of sight, with the film plane tilted 30 degrees toward him.

The light source scan arm is positioned so that the light source is perpendicular to the film plane. This projects the light downward and towards the rear of the instrument.

A first surface mirror, mounted parallel to the film plane (in the left-right attitude) is mounted to intercept the beam at about the height of a standing operator's thighs.

The mirror reflects the beam back toward the operator, in a plane parallel to the floor, onto the copy easel.

The easel may be located at angles from approximately -5 to +20 degrees to the beam in the vertical attitude, and parallel to the floor in the left-right attitude.

Orientation of the input film is roughly horizontal and that of the copy film is roughly vertical. These attitudes are modified by the initial and variable tilts of the instrument.

Because the instrument will be permanently installed in a darkroom, will not be operated under roomlight conditions, and because it is necessary for the operator to have quick and convenient access to components, no external skin is provided.

A description of the various components and assemblies of the instrument is given in the following:

2.4.1 Scan Arm Assembly

The scan arm assembly consists of the projection light assembly, the cooling fan, and the scan arm drive.

2.4.1.1 Projection Light Assembly

The projection light assembly consists of a pre-focused, type DFR, 500 watt projection lamp, a series of condenser elements, a 4358°A interference filter, and an adjustable width slit.

All are enclosed in a light-tight, ventilated metal housing that is mounted on the upper surface of the scan arm. Light tight louvres are inserted in the housing walls to facilitate the flow of cooling air around the lamp.

The condenser set is of suitable focal length and relative aperture to focus the lamp filament into the projection lens and fill its aperture. The conventional circular shape of the condenser elements is modified by slabbing them to a central rectangular shape similar to the shape of the required rectangular exposure beam.

The slit is mounted on the lower surface of the lamp housing below the condenser elements. Its attitude is such that the long dimension of the beam projected through it is perpendicular to the long axis of the input film. The slit is manually adjustable through a width range of from .1 to 5 mm, but should be set at lmm for optimum performance.

The interference filter is roughly the same shape as the modified condenser elements, and is mounted in line between the condensers to filter the heat producing the frequencies from the projected light and to modify the light to the proper spectral characteristics for optimum lens performance.

2.4.1.2 Cooling Fan

The cooling fan is a Rotron "Muffin" fan that is mounted on the scan arm at the rear of the light source housing. It is physically coupled to an opening in the rear wall of the housing by a length of flexible air-duct material. Isolation mounts are employed to prevent transmission of fan vibrations to the scan arm.

The rotation of the blades and the mounting convention are such that the induced flow draws air through the housing louvres, around the lamp, and then exhausts it to atmosphere.

The fan is connected electrically so that it is energized when the main power control is turned on.

2.4.1.3 Scan Arm and Drive Assembly

The scan arm and drive assembly consists of the drive arm, the drive motor, the drive rail, and v-ways, the exposure control mechanism, the travel limit switches, and the counterweight.

The drive arm is pivot mounted to the support plate of the main framework so that when the arm is rotated about the pivot point, the lamp housing swings through an arc concentric with the negative film platen. A spur gear is rigidly fastened to the arm at the pivot point location so that it rotates in the same manner as the arm. This gear is a component of the exposure control mechanism.

The drive rail is mounted on the rear surface of the support plate in an attitude perpendicular to the drive arm (when the arm is in the nadir position). The rail is spaced away from the plate so that the drive arm may swing between it and the plate.

The drive motor is mounted on a movable carriage support that is in turn mounted to the drive rail by guides, an idler wheel and a friction wheel. The friction wheel is coupled through a mechanical linkage to the shaft of the drive motor so that when the motor rotates, the carriage is driven along the rail.

The drive carriage is coupled to the sliding unit of the v-way assembly, which is in turn fastened to the drive arm. As the carriage is translated along the rail it swings the arm through its arc by applying its force at continuously varying radii. This serves to modify the arm velocity so that it varies from minimum at the start of the swing, to maximum at the center, and then decreases to minimum at the end. This in part serves to produce uniform exposure at the copy easel.

The limit switches are mounted at both ends of the drive rail to prevent overtravel, and to reverse the scan drive circuitry for the next succeeding exposure.

The exposure control consists of a drive gear, an idler gear, and a driven gear. The drive gear (as mentioned above) is fastened to the drive arm, the driven gear is coupled to the armature shaft of a variable transformer that is electrically connected with the drive motor power line. As the arm rotates the motor voltage variation further modifies the sweep velocity as required to produce even exposure of the copy film.

2.4.1.4 Counterweight

The counterweight is fastened to the lower portion of the drive arm. Its weight and moment arm are equal to the weight and moment arm product of the upper portion of arm so that the assembly is balanced.

2.4.2 Negative Film Platen

The negative film platen assembly consists of a pair of curved film support tracks, the roll control assembly, and a set of film support rollers.

The support/guide tracks are mounted by the cantilever method to the front surface of the framework's main support plate. The radius of curvature of their upper (convex) surfaces is 0.010 inches less than the constant short conjugate of the projection system.

The tracks are spaced apart so that about .25 inch of the negative film edge is supported by each, leaving a clear space of about 2.25 inch between their inner edges for projection. They are equipped with film edge guides, and the inner track has a cutaway area to allow projection of the format edge data and for alignment of the nadir fiducial mark with the roll indicator. The upper surfaces of the tracks are polished and hard plated to preclude film damage.

The roll control assembly consists of a scale, a backlighting mechanism, and a sliding indicator.

The scale is graduated and marked over a length of 210mm. The zero point is at the center of the graduations, and markings are in 1mm increments toward each end for 105mm. The scale is mounted parallel to, and inboard of, the inner guide track with its zero mark coincident with the projection nadir point.

The backlighting mechanism is an electrical glow plate that may be swung up under the negative film to facilitate aligning the indicator and fiducial marks. It has a safety interlock that prevents scan arm travel when it is swung into the viewing position.

The sliding indicator is of clear plastic with an opaque center (witness) marking. It is mounted so that it has freedom to move parallel to the scale (with the witness mark perpendicular to it) and limited freedom to move perpendicular to the scale so that the end of the mark can be moved partially into the format area for aligning it with the negatives nadir fiducial mark.

The film support rollers are four parallel free-wheeling rollers mounted on the drive arm so that the arm swings them in an arc between the film support tracks. Their location is such that the radial trace of their upper surfaces is exactly equal to the taking lens focal length, less the thickness of the input film.

As the rollers are swung with the drive arm, the section of the film that is being instantaneously projected is lifted slightly by the rollers so that the film emulsion is precisely positioned at the correct conjugate distance for geometric fidelity of the image.

2.4.3 Negative Film Transport System

The negative film transport system consists of two film spool spindles, two drive rollers, a tension roller, three pressure/wrap rollers, a manual transport control, an endless belt link chain assembly, a magnetic brake, and three torque motor assemblies. The entire system is mounted on the framework's main support plate.

The film spindles are mounted at either end of the negative platen so that the film runs from one spool (mounted on the spindle), through the platen assembly, and onto the other spool. Each spindle is coupled through a bevel gear train to a torque motor. The motor rotation convention is that required to wind film onto its respective spool with the emulsion side inboard.

A drive roller is mounted at either end of the platen between the platen end and the film spindle. The pressure/wrap rollers are mounted with spring-loaded, hinge type supports so that their surfaces rest in contact with the surfaces of the drive rollers at locations that wrap the film around the drivers. The wrap rollers may be swung away from the drive rollers for loading or adjusting the film.

The ends of the drive roller spindles at the rear side of the support plate are equipped with chain drive sprockets and the endless chain couples the two rollers together. A series of idler sprockets guides the chain and maintains it in tension.

The transport manual control is a handwheel located on the front of the support plate at the operator's right hand. It is connected to the driving sprocket through a push-pull mechanical clutch so that when the clutch is engaged rotation of the handwheel causes the drive rollers to transport the film in either direction. The push-pull action of the handwheel shaft also operates a micro-switch that controls a magnetic brake connected to the driving sprocket, When the clutch and handwheel are engaged (pushed in) the brake is de-energized and the sprocket drive may be rotated. When the clutch and handwheel are dis-engaged (pulled out) the brake is energized to prevent unwanted film motion.

The tension roller is mounted on the support plate between the left end (looking from the front) of the film platen and the left hand driver. It is equipped with a hinge mounted pressure/wrap assembly similar to that of the drive rollers. The tension roller is coupled through a gear train to a torque motor. The motor is connected electrically so that its rotation applies force to the film in a right to left direction to maintain tension when the drive roller brake is energized. The amount of tension may be regulated through a variable transformer located on the control chassis.

2.4.4 Projection Lens Assembly

The projection lens assembly consists of the lens, the lens mounting, the lens drive and focusing mechansim, the Scheimpflug adjustment mechanism, and the folding mirror.

The projection lens is specially designed and fabricated by [redacted] for the Gamma I. This component, nominally f/12 at infinite conjugates, has a focal length of 15.800 inch ±.010 inch and is essentially diffraction limited on axis at 4358 Angstroms, the wavelength for which it is optimized. A narrow band interference filter in the condenser system provides proper spectral selection. An adjustable iris diaphragm is included to provide illumination control, and to furnish a possible capability of improving the overall characteristics of the system through the use of reduced aperture. The lens elements are overcoated with magnesium fluoride and their edges are blackened to reduce internal reflections. STAT

The lens design is a modification of the classic GAUSS type. In the design program, it was found that to obtain high resolution based on flat field and minimum distortion it was necessary to make the nodal points and exit pupils all coincident with each other. This dictated that the first and last system elements be negative, in order to superimpose the pupils and nodal points.

As a result of the design procedures and fabrication techniques, the residual optical distortion is very small, having a magnitude of about 0.003"at approximately 17 degrees off axis. Figure 1 shows a distortion curve typical of this design. Such distortion as does exist is radially symmetrical and thus

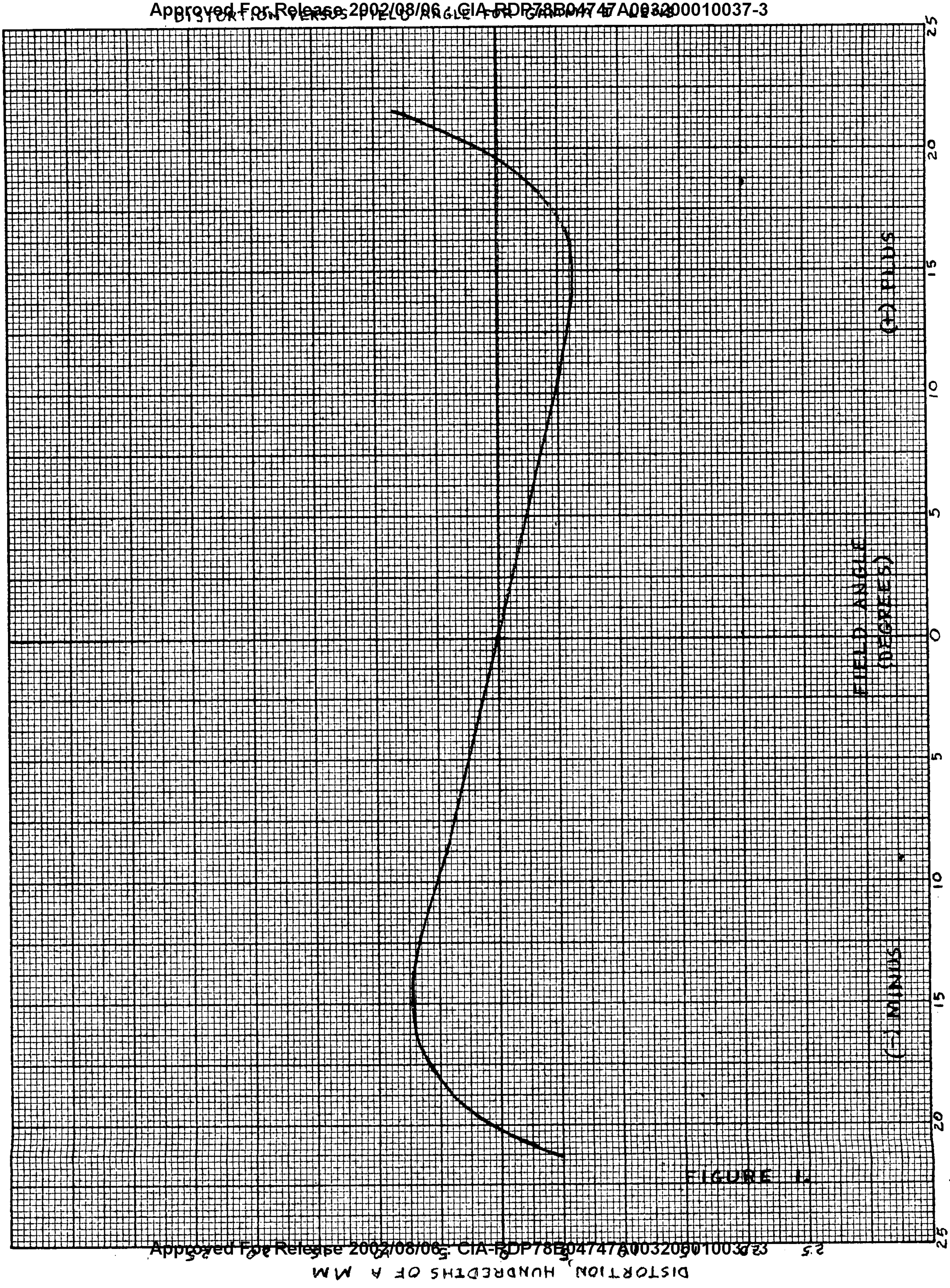
DISTORTION VERSUS FIELD ANGLE
FIELD ANGLE
(DEGREES)
(+) PLUS
(-) MINUS
25
20
15
10
5
0
5
10
15
20
25
DISTORTION, HUNDREDTHS OF A MM

FIGURE 1.

allows the possibility of minimizing geometrical distortion by judicious adjustment of the point of lens rotation. This is of significant importance because, even if there were no inherent distortion, geometric fidelity could be lost if the lens were rotated about an incorrect axis.

The lens has been thoroughly tested on a precision [redacted] nodal slide bench STAT
to determine accurately its focal length, rotation axis (for trunnion location), distortion characteristics, and resolution capabilities through the required scan angle.

The lens drive and focusing mechanism consists of the lens mounting bracket, the driven gear train, the focusing cam and follower, and the driving gear train.

The mounting bracket is a gimbal suspension assembly that is pivot mounted to the support plate so that it is free to rotate through the maximum exposure scan arc. The inner and outer gimbals support the lens so that it has limited freedom to swing on two sets of trunnions located at right angles to each other in a plane perpendicular to the projection axis. One set of trunnions allows rotation about the Scheimpflug axis, the other about the focusing axis. The entire assembly is driven about the pivot point with the lens attitude set by the Scheimpflug and focusing adjustments.

The driving gear train consists of a drive spur gear fastened to the base of the mounting bracket, a sector gear pivoted on the support plate, and a rack that is attached to and driven by the cam follower.

The focus cam is a three dimensional cam that adjusts the angular position of the lens (around the focus axis) to maintain sharp focus throughout the scan angle of 80 degrees. It compensates for the change in projection distances that result from varying the easel position for tilt compensation. Its shaft is coupled to the scan arm at the arm pivot point through the driven gear train so that when the arm rotates the cam rotates with it, and in turn rotates the lens assembly at variable differential velocities through the cam follower and the driving gear train.

The Scheimpflug adjustment consists of a mechanical linkage, an indicator, and a control knob. Operation of the control swings the lens about the Scheimpflug axis to the correct angle for the taking parameters of the individual frame.

The folding mirror is located and rigidly mounted on the main framework between the lens and the copy plane in such a location that the projected light beam is transmitted onto the easel at all possible lens and easel setting combinations.

It is a piece of optical quality glass that has been polished flat to within 1 1/4 fringes over its surface. Its dimensions are 20 inches long by 6 inches wide by 1 1/2 inches thick. The front surface is aluminized and overcoated with silicon monoxide. It is mounted by a three point suspension method that precludes physical deformation of the surface.

2.4.5 Copy Easel

The copy easel is a thin metal plate that is shaped to the configuration of a cylindrical section. The plate has longitudinal grooves coupled through a plenum to an air-flow pump so that differential pressure may be created over the surface to hold the film firmly against the curved surface during the photographic exposure. The surface of the plate that contacts the base of the film is coated with bonded Teflon to preclude film damage. Edge guides are provided to enhance the pneumatic hold down and to facilitate film transport.

The radius of curvature of the plate may be varied by eight screw type control mechanisms that exert force against the rear surface of the plate to modify its configuration. Each of the controls has a dial indicator that shows the displacement of its associated section of the plate from an established norm. The displacement is indicated in 0.001 inch increments. Easel curvature is a function of taking altitude and tilt angle and the information relative to this is transmitted to the operator along with the negative film.

The easel plate and the radius control mechanisms are mounted perpendicular to the projection axis and may be tilted manually in a vertical plane through a range of from -5 degrees to +20 degrees. The tilt mechanism consists of a trunnion mounting and a worm and wheel drive provided with a vernier position indicator. A handwheel located at the operator's right serves to vary the tilt setting in accordance with the taking parameters.

The entire easel (and the film transport system) is mounted on a sliding carriage that allows translation along the projection axis. A precision machine tool cross-slide mechanism is the main component of this mounting.

A conventional manual crank control equipped with a micrometer type indicator is utilized to translate the assembly as required to compensate for the tilt setting of the easel.

2.4.6 Copy Film Transport System

The copy film transport system is comprised of the supply and take-up spindle assemblies, the drive mechanism, the copy easel, and the guide and wrap rollers.

The spindle assemblies are mounted at either end of the copy easel, the supply unit is at the operator's right and the take-up unit at the left. Each has a stub spindle that is permanently located, and a spring loaded movable spindle that may be swung out of the way for loading and unloading the 500 foot 9 1/2 inch wide film spools that the system accommodates. Both stub spindles are equipped with brake drums and an adjustable constantly acting band brake is employed to apply drag to its respective shaft. The fixed and movable stub ends are designed to mate with the core openings and keyways of MIL-Std film spools. In addition to the drag brake, the take-up fixed stub spindle is coupled through a bevel gear train to a torque motor whose rotation tends to wrap film onto the take-up spool, emulsion side inboard.

The copy easel has been described in section 2.4.5. This unit serves (in the transport system) as a film guide and support.

The drive mechansim consists of a neoprene covered drive roller that is mounted in the take-up assembly housing, a drive motor, a gear train, a commercial, manually variable, speed reducer, and a cam and switch timing arrangement. The drive roller is coupled to the motor through the gear train, speed reducer, and timing device in such a manner that variation of the reducer output ratio varies the number of rotations that the drive roller makes per a number of rotations of the drive motor. As the film transport signal initiates a total revolution response from the drive motor, adjustment of the reducer varies the length of film transported per exposure cycle.

The guide and wrap rollers are free wheeling idlers strategically located in the supply and take-up housings to guide the film through the transport path and to wrap the film around the drive roller as required to assure positive drive.

The combination of drag brakes and take-up torque motor assures that the film remains under tension in both the power on and power off conditions to prevent sagging or buckling.

2.4.7 Controls

The controls are located at various positions on the instrument and on the control panel which is located at the front of the instrument above the easel at the operator's thigh.

Those controls which govern the operational functions are located on the control panel. Those that serve to set up and/or adjust the instrument, are positioned at locations conveniently near to the functions, components, or mechanisms that they control.

2.4.7.1 Power Control

The power control is an illuminated push-button switch located on the control panel. It serves to energize all of the electrical circuitry of the instrument.

2.4.7.2 Panel Illumination Control

The panel illumination control is a rotatable knob located on the control panel. It controls the panel illumination voltage to vary the intensity of the several dial lights.

2.4.7.3 Projection Lamp Voltage Control

The lamp voltage control is a two position rotatable knob located on the control panel. The two positions are marked NORM and HIGH. It serves to select one of two pre-determined projection lamp voltages as required by the general density level of the input film. This unit is a component of the instruments exposure control system.

2.4.7.4 Scan Time Control

The scan time control is a rotatable knob control of a variable rheostat located on the control panel. The face of the panel in its vicinity is marked in a circular pattern with positional marks in increments of from 0 - 100. The control serves to vary the base voltage of the scan arm drive motor transformer and hence partially controls the photographic exposure.

2.4.7.5 Print Control

The print control is an illuminated pushbutton switch located on the control panel. It serves to initiate the automatic exposure/transport cycle.

2.4.7.6 Focus Control

The focus control consists of a manually operated handwheel crank and a five digit counter, both are located at the lower right front surface of the main support plate. It serves to position the three-dimensional focus cam in accordance with the stated altitude of the negative frame. The counter reading indicates the setting in kilo-foot increments.

2.4.7.7 Scheimpflug Control

The Scheimpflug control consists of two rotatable control knobs, a locking mechansim, and a vernier scale indicator.

Either of the control knobs adjusts the position of the lens around the Scheimpflug axis, the locking mechansim maintains the selected position, and the indicator indicates the Scheimpflug angle to within 0.10 degrees.

2.4.7.8 Easel Translation Control

The easel translation control is a manually operated crank equipped with a micrometer collar indicator graduated in 0.001 inch increments. This control is located at the lower right front of the instrument. It serves to translate the easel forward and backward in a line parallel to the floor to give the correct projection conjugate for the established tilt angle.

2.4.7.9 Easel Tilt Control

The easel tilt control consists of a manually operated crank handwheel located at the right of the easel translation control, and a scale type indicator located at the rear center of the easel plate. The control serves to rotate the easel in its tilt trunnions to the required tilt angle. The indicator indicates the tilt angle in 0.10 degree increments.

The tilt control is operated in combination with the easel translation control to settings established by the taking attitude and tilt angle.

2.4.7.10 Easel Curvature Control

The easel curvature control consists of eight manually operated handwheel cranks and eight dial indicators.

The crank/indicator sub-assemblies are evenly spaced from nadir along the the top rear surface of the easel plate.

The cranks serve to vary the easel curvature locally and the indicators indicate the local variation of curvature, from an established norm, in .001 inch increments.

The curvature controls are operated in combination with the focus control to settings established by the taking altitude and tilt angle.

2.4.7.11 Negative Transport Control

The negative transport control is a manually operated handwheel crank located at the top outer surface of the main support plate at the operator's right. It may be pushed in to engage it with the drive roller gear train and to release the magnetic brake.

When the control is pushed in, rotation of the control causes the film to be transported in the direction of rotation. When the control is allowed to snap out, it is automatically disengaged from the gear train, and the magnetic brake is re-clamped to lock the drive roller.

2.4.7.12 Slit Control

The slit control is a metal lever at the lower end of the projection light housing. It has freedom to move in a plane perpendicular to the film transport axis.

When the slit lever is pushed all the way in, the slit width is maximum. When it is pulled all the way out, the slit width is minimum. This component serves as part of the instrument's exposure control system.

2.4.7.13 Copy Film Metering Control

The copy film metering control is a lever that is an integral component of the film drive speed reducer located at the lower left of the easel assembly.

The lever varies the output velocity of the speed reducer, and hence, the length of film transported by the automatic cycle.

2.4.7.14 Negative Film Tension Control

The negative film tension control is the integral control knob of a POWERSTAT variable transformer connected in the tension torque motor power line. The control is located on the top panel of the control chassis, and serves to vary the torque motor voltage, and consequently, the negative film tension.

2.4.7.15 Vacuum Control

The vacuum control is a two position toggle switch located on the top panel of the control chassis. It is connected to the vacuum solenoid valve so that it can override the automatic vacuum switching circuitry for making local adjustments to the copy film at the easel.

2.4.8 Electrical Circuitry and Components

The electrical circuitry and components, with the exception of locally positioned motors, switches and cables, is contained in the control chassis that is mounted in the main framework.

This unit has quick disconnect electrical coupling with the components it serves so that it may be readily removed for service.

2.4.9 Slide Rule - Gamma I Setup

A specialized individual slide rule has been designed and fabricated for each of the Gamma I instruments.

This device converts the several input taking parameters into actual machine settings for altitude, Sbheimpflug, tilt, easel translation, and easel curvature. The settings are transmitted to the operator along with the film so that he may make his setup without first making calculations.

2.5 Equipment Operation

The negative film is examined prior to rectification and its taking parameters are reduced to instrument settings by use of the slide rule. These settings are listed on a data sheet that references the settings to specific frames.

After examination/reduction procedure has been completed, the film and data sheet are transmitted to the Gamma operator who then performs the following sequence of operations:

2.5.1 Readying Negative Film

The negative film is loaded onto the supply spindle, threaded through the transport path in accordance with a loading diagram, and fastened to the core of the take-up spool.

After loading, the film is transported until the desired frame is in the exposure area. The nadir offset pointer is set to the roll setting indicated by the data sheet and the frame fiducial mark is aligned with the pointer. In this latter operation, the nadir glow plate is used to facilitate alignment and then returned to its storage position.

2.5.2 Tilt Compensation

Tilt is compensated for by observing the following procedures:

2.5.2.1 Easel Tilt

The easel tilt control is set to the angle specified by the film data sheet.

2.5.2.2 Scheimpflug Adjustment

The Scheimpflug control is adjusted to the angle specified by the film data sheet, and then locked in place at this setting.

2.5.2.3 Easel Translation

The easel translation control is operated to move the easel to the position indicated by the data sheet and the tilt angle setting.

2.5.3 Altitude Compensation

After the tilt compensations have been completed, the instrument is adjusted for altitude compensation in accordance with the following procedures:

2.5.3.1 Focus Cam Setting

The focus (altitude)control is set to the reading specified by the film data sheet.

2.5.3.2 Easel Curvature Adjustment

Adjust each of the easel curvature controls to the settings specified by the film data sheets.

2.5.4 Readying Copy Film

Copy film is loaded onto the supply spindle, threaded through the transport path in accordance with a loading diagram, and fastened to the core of the take-up spool. Then the transport system is cycled to transport fogged film out of the exposure area. A check of the metering response is made at this time, and the transport control is adjusted as required.

2.5.5 Exposure

After the negative and positive films have been loaded and the several adjustments have been performed, the exposure control system is adjusted to the optimum setting for the mean density of the input material. This is accomplished by setting the Scan Arm Velocity and Light Intensity controls and the slit width control level.

When the exposure control adjustments have been made, the Print control is activated to initiate the automatic exposure/transport cycle.

After the desired number of prints has been made (one print per operation of the Print control) the negative film is transported to the next significant frame and such adjustments as are indicated by the data sheet are made prior to exposure of that frame.

2.6 Acceptance Tests

To assure conformance with the contract provisions, acceptance testing shall be performed prior to and following delivery of the instrument, in accordance with Design Specifications - Gamma I Printer, dated 10 April 1963.

2.6.1 Inspection and Test

Equipment shall be inspected and tested for machine and final product accuracy and to determine conformance with the requirements of this specification at the manufacturer's plant prior to delivery.

2.6.1.1 These tests shall be performed by the contracting agency's project engineer attended by a GIMRADA technical representative. The tests shall be conducted in accordance with the Acceptance Test Plan. STAT

2.6.2 Endurance Test

Prior to final acceptance, the instrument shall be given a 16 hour endurance test at facilities to further determine the performance of the equipment under operational conditions. In the event of failure, necessary maintenance shall be made and the test repeated.

STAT

2.6.2.1 This test shall be performed by the contracting agency's project engineer.

2.6.2.2 Contracting agency's operating personnel who will perform the engineer test shall be trained during this period.

2.7 Engineer Test

Following acceptance of the instrument from the contractor, the engineer test shall be conducted in accordance with this plan of test.

III REFERENCES

3.1 Publications

The following publications are concerned with this equipment:

STAT 3.1.1 PANORAMIC PROGRESS

3.1.2 DESIGN PLAN EN-71 RECTIFYING PROJECTION PRINTER

3.1.3 FINAL REPORT, EN-71 RECTIFYING PROJECTION PRINTER

3.1.4 DESIGN STUDY, GAMMA I & II

3.2 Plan of Test

The following plan of test prepared by is applicable to this plan of Engineer Test: 25X1

3.2.1 Acceptance Test Plan for Gamma I Rectifying Printers

3.3 Report Writing

The following references are related to the reporting of the tests described in this plan.

3.3.1 There have been no specifications or guides defined for reporting the tests herein included.

IV INSTRUMENTAL TESTS

Precede the instrumental tests by a weight and size determination check.

Objective: Determination of the weight and size must be made to estimate floor requirements for installation as to bearing and vibration, and for working space requirements.

Procedure: Weigh the incoming shipment on freight scale as packed. Unpack and install; then weigh the packing and the crate. Measure the overall size, allow sufficient working space.

Data: Record the net size and weight in the test notebook

4.1 Objective

The objective of the instrumental tests is to determine that the Gamma I instrument performs all of its physical (mechanical and electrical) functions in a satisfactory and reliable manner.

4.2 Procedures

The instrumental test shall be performed in accordance with the procedures defined in the following paragraphs:

4.2.1 Negative Film Transport Test

4.2.1.1 Test Objectives

To determine that the transport system may be satisfactorily controlled to transport and position film to the required accuracies, that the film is held precisely at an established position under all conditions, and that the film tension mechanism does not deform the film track nor cause film to be pulled from the path.

4.2.1.2 Test Equipment

The following equipment is required for the proper performance of this test;

4.2.1.2.1 500' of processed 70 mm negative film contained on a MIL-STD spool.

4.2.1.2.2 China marking (grease) pencil .

4.2.1.3 Test Procedure

4.2.1.3.1 Load the negative film in the approved manner.

4.2.1.3.2 Operate the handwheel control, with the Power control "on", and observe that film may be transported in either direction without undue physical effort or damage to film.

4.2.1.3.3 Observe that the film tension is sufficient to prevent buckling or sagging without pulling the film out of the guides, both when film is stopped and being transported.

4.2.1.3.4 Make a grease pencil mark on the film's emulsion surface and operate the transport control to move the mark into coincidence with the roll control witness mark.

4.2.1.3.5 Observe that the marks remain in coincidence when the handwheel is dis-engaged from the chain/roller drive mechanism.

4.2.1.3.6 Initiate an exposure cycle and observe that the mark coincidence is accurately maintained during and after the scan arm sweep.

4.2.1.3.7 Turn the Power control "off" and then "on". Observe that the mark coincidence is accurately maintained during these procedures.

4.2.1.4 Test Data

Record the results of the test in accordance with the following:

Test Element	Test Results (check one)	
	Satisfactory	Unsatisfactory
Ease of bi-directional transport (4.2.1.3.2).......................		
Film Tension (4.2.1.3.3)...................		
Ease of nadir alignment (4.2.1.3.4).......................		
Alignment stability-handwheel disengagement (4.2.1.3.5)..........		
Alignment stability during and after exposure scan (4.2.1.3.6)..........		
Alignment stability in power "off" & "on" conditions....(4.2.1.3.7)...................		

4.2.2 Projection Light Source Test

4.2.2.1 Test Objectives

To determine that the projection lamp is properly powered for each of the two operational settings that the cooling system functions properly, and that the housing is light tight.

4.2.2.2 Test Equipment

Volt-ohm meter, Simpson# 260 , or equivalent.

4.2.2.3 Test Procedures

4.2.2.3.1 Connect the leads of the volt-ohmmeter to terminals #1 and #2 of TB-112. Set meter to read in the 100 - 200 volt range.

4.2.2.3.2 Turn the Projection Lamp Voltage Control to NORM and then turn the Power control to "on". Observe that the voltmeter reads 115 volts $\pm$ 5 volts.

4.2.2.3.3 Turn the Projection Lamp Voltage Control to HIGH. Observe that the voltmeter reads 135 volts $\pm$ 5 volts.

4.2.2.3.4 Check that the cooling fan is operational when the power is turned on by holding hand near the fan exhaust port.

4.2.2.3.5 Darken the test area and initiate an exposure cycle with the projection Lamp Voltage Control turned to HIGH. Observe that the only light visible is that which is projected through the housing slit. Pay particular attention to the ventilation louvres.

4.2.2.4 Test Data

Record the test results in accordance with the following:

TEST ELEMENT	TEST RESULTS (check one)	
	SATISFACTORY	UNSATISFACTORY
NORM Voltage (4.2.2.3.2)..................	*	*
HIGH Voltage (4.2.2.3.3)..................	*	*
Cooling Air-Flow (4.2.2.3.4)..............		
Light Tightness (4.2.2.3.5)...............		

*Record the observed voltage readings in the appropriate column.

4.2.3 Scan Arm Test

4.2.3.1 Test Objectives

To determine that the scan arm sweep rate control performs its operational function correctly, and that the scan arm drive mechanism operates smoothly and without observable mechanical chatter.'

4.2.3.2 Test Equipment

Stop Watch -.010 second increments.

4.2.3.3 Test Procedures

4.2.3.3.1 Turn the Power control "on" and set the Scan Time control to its lowest (zero) setting.

4.2.3.3.2 Actuate the Print control and start the stop-watch when the arm starts to rotate. Stop the watch at the same instant the arm stops.

4.2.3.3.3 Observe that the elapsed scan period for the lowest (zero) control setting is ten (10) seconds ± 1 second.

4.2.3.3.4 Set the Scan Time control to the middle (50) of its range.

4.2.3.3.5 Actuate the Print control. Start and stop the watch in coincidence with scan arm rotation.

4.2.3.3.6 Observe that the elapsed scan period for the middle (50) setting is thirty (30) seconds ± 2 seconds.

4.2.3.3.7 Set the Scan Time control to its highest (100) setting.

4.2.3.3.8 Actuate the Print control, Start and stop the watch in coincidence with scan arm rotation.

4.2.3.3.9 Observe that the elapsed scan period for the highest (100) control setting is sixty (60) seconds ± 2 seconds.

4.2.3.3.10 During all of the above exposure scans, observe the amount of mechanical chatter in the arm drive. This should be undetectable without instruments.

4.2.3.4 Test Data

Record the test results in accordance with the following:

TEST ELEMENT	TEST RESULTS (check one) SATISFACTORY	UNSATISFACTORY
Elapsed Time-Fast Scan (4.2.3.3.3)..........	*	*
Elapsed Time-Median Scan (4.2.3.3.6).........	*	*
Elapsed Time-Slow Scan (4.2.3.3.9)..........	*	*
Absence of observable mechanical chatter (4.2.3.3.10)..............		

*Record the observed time period in the appropriate column.

4.2.4 Lens Drive Test

4.2.4.1 Test Objectives

To determine that the lens drive mechanisms function in a satisfactory manner.

4.2.4.2 Test Equipment

No special equipment is required for the performance of this test.

4.2.4.3 Test Procedures

4.2.4.3.1 Operate the focus control through its full range and observe that it moves freely without binding or other restrictions.

4.2.4.3.2 Operate the Scheimpflug control through its full range (+8 degrees to -2 degrees). Observe that the control and lens move freely without binding or other restrictions.

4.3.4.3.3 Initiate exposure cycles at various focus and Scheimpflug setting combinations. Observe that the lens scans without detectable mechanical chatter.

4.2.4.4 Test Data

Record the test results in accordance with the following:

Test Element	Test Results (check one)	
	Satisfactory	Unsatisfactory
Focus Control (4.2.4.3.1)..................		
Scheimpfulg Control (4.2.4.3.2)............		
Lens Drive (4.2.4.3.3).....................		

4.2.5 Copy Stage Test

4.2.5.1 Test Objectives

To determine that the easel curvature is satisfactorily cylindrical, and that the curvature, tilt, and translation controls function mechanically in a satisfactory manner.

4.2.5.2 Test Equipment

Special easel curvature test guage.

4.2.5.3 Test Procedures

4.2.5.3.1 Load film through the easel and turn Power control "on" to apply vacuum to the film.

4.2.5.3.2 Set curvature controls to normal (all dials at zero). Apply the test guage to the easel surface and observe the amount of deviation (if any) from a true cylindrical configuration as indicated by the guage.

4.2.5.3.3 Operate each of the several curvature controls. Observe that the mechanisms operate smoothly and that the indicators follow correctly.

4.2.5.3.4 Operate the tilt control and observe that it and the easel move freely without restriction or chatter.

4.2.5.3.5 Operate the easel translation control, Observe that the control rotates freely and that the easel is translated without restriction or chatter.

4.2.5.4 Test Data

Record the test results in accordance with the following:

Test Element	TEST RESULTS (Check One)	
	Satisfactory	Unsatisfactory
Easel Curvature (4.2.5.3.2)....................	*	*
Curvature Controls (4.2.5.3.3)...............		
Tilt Mechanism (4.2.5.3.4).....................		

*Record the measured deviation in the appropriate column.

4.2.6 Copy Transport Test

4.2.6.1 Test Objectives

To determine that all mechanical and electrical functions of the copy transport system operate satisfactorily and reliably, and that the film is consistantly metered in the correct increments.

4.2.6.2 Test Equipment

4.2.6.2.1 Flexible steel measuring tape -10' length, 1/16" increments.

4.2.6.2.2 China Marking (grease) pencil.

4.2.6.3 Test Procedures

4.2.6.3.1 Load the instrument with 9½" wide film in the specified manner.

4.2.6.3.2 Actuate the Print control and observe that the film is transported automatically at the end of the exposure sweep. Check that the film does not buckle or sag, either when moving or stopped.

4.2.6.3.3 With the Power control "on", turn the vacuum override switch to "off" and observe that vacuum is released at the easel. Turn the switch "on" and observe that the vacuum is re-applied.

4.2.6.3.4 Use the grease pencil to mark the top surface of the film at a location near the right hand side of the easel. Make a witness mark on the instrument surface that is coincident with the film mark.

4.2.6.3.5 Initiate an exposure/transport cycle.

4.2.6.3.6 Use the tape and measure the distance between the film mark and the witness mark. The transport increment should be 84" ± ¼".

4.2.6.3.7 Make a new mark on the film coincident with the existing witness mark.

4.2.6.3.8 Initiate an exposure/transport cycle and again measure the transport increment. Repeat three times. Observe and record the repeatability of the increment.

4.2.6.4 Test Data

Record the test results in accordance with the following:

TEST ELEMENT	TEST RESULTS (check one) Satisfactory	Unsatisfactory
Transport Operation (4.2.6.3.2).............		
Vacuum Override (4.2.6.3.3).............		
Transport Metering (4.2.6.3.6).............	*	*
Metering Consistancy (4.2.6.3.8).............	**	**

* Record the measured increment in the appropriate column.

**Record the average deviation in the appropriate column.

4.2.7 Operating Controls Test

4.2.7.1 Test Objectives

To determine that the operating controls perform their specified functions in a satisfactory manner.

4.2.7.2 Test Equipment

4.2.7.2.1 Volts-ohm meter - Simpson #260 or equivalent.

4.2.7.2.2 Stopwatch - .01 second increments.

4.2.7.3 Test Procedures

4.2.7.3.1 Turn the Power control "on". Observe that the panel lights are illuminated, that the vacuum pump is energized, and that the lamp cooling fan operates.

4.2.7.3.2 Operate the Control Panel Illumination control. Observe that it varies the intensity of all control panel illumination.

4.2.7.3.3 Connect the voltmeter leads to terminals #1 and #3 of TB-112. With the Projection Lamp Voltage control set at NORM, turn the Power control "on" and observe that the meter reads 115 volts. Turn the Projection Lamp Voltage control to HIGH and observe that the voltmeter reads 135 volts. Disconnect the voltmeter.

NOTE: THIS TEST ELEMENT MAY BE PERFORMED SIMULTANEOUSLY WITH ELEMENTS OF THE "PROJECTION LIGHT SOURCE TEST" (4.2.2).

4.2.7.3.4 Activate the Print control. Observe that an automatic exposure/transport cycle is initiated.

4.2.7.3.5 Turn the Scan Time control to zero. Initiate an exposure/transport cycle. Use the stopwatch to determine that the elapsed scan time is approximately ten (10) seconds. Turn the control to 100, initiate another cycle and observe that the elapsed scan time is approximately sixty (60) seconds.

NOTE: THIS TEST ELEMENT MAY BE PERFORMED SIMULTANEOUSLY WITH ELEMENTS OF THE "SCAN ARM TEST" (4.2.3).

4.2.7.4 Test Data

Record the test results in accordance with the following:

TEST ELEMENT	TEST RESULTS (check one) SATISFACTORY	UNSATISFACTORY
POWER Control...................... (4.2.3.7.1)		
PANEL ILLUMINATION Control......... (4.2.7.3.2)		
LAMP VOLTAGE Control............... (4.2.7.3.3)		
PRINT Control...................... (4.2.7.3.4)		
SCAN TIME Control.................. (4.2.7.3.5)		

4.2.8 Electrical System Test

4.2.8.1 Test Objectives

To determine that all components function in a satisfactory manner.

4.2.8.2 Test Equipment

None Required

4.2.8.3 Test Procedures

Check operation of all electrical components, switches, and knobs to determine efficiency of operation.

4.2.8.4 Test Data

Record whether the operation is satisfactory or unsatisfactory. Specify which, if any, component is unsatisfactory and the reason why.

4.3 Results

The results of the instrumental tests shall be analyzed in terms of operational suitability and reliability.

V PHOTOGRAPHIC TEST

5.1 Objectives

To determine that the Gamma I Printer performs its photographic (resolution, magnification, and eveness of exposure) functions in accordance with the specified parameters.

5.2 Test Equipment

5.2.1 Test Negative

Specifically designed and fabricated for this test. This shall be on 70 mm wide film and its test pattern shall be distributed over a length analogous to an operational input frame. The test pattern shall consist of a grid whose scale varies from center towards both ends. The variation shall be such that the rectifier (setup with 15^{o} tilt and 0^{o} roll, and with the easel curvature and focus set for nominal altitude) should theoretically produce copy whereon all grid squares are of the same dimensions. In addition to the grid pattern, the format shall have strips of high contrast resolution target (USAF 1951 STD) images oriented perpendicular to the long axis of the test format. The targets shall have a minimum resolution of 180 1/mm.

5.2.2 Mensuration Equipment

Monocular optical comparater

5.2.3 Copy Film

9½" wide Type 5427 Aero-Dupe unexposed film contained on a MIL-STD spool.

5.2.4 Microscope

Binocular Type - 35X magnification

5.2.5 Processing Equipment

Standard darkroom equipment for processing strip film.

5.3 Test Procedure

5.3.1 Load the instrument with the test film.

5.3.2 Set the easel tilt control and the Scheimpflug control to the corresponding setting.

5.3.3 Set the focus control and the easel curvature controls to the correct setting for nominal altitude.

5.3.4 Load the test negative into the negative platen. Set the roll control pointer at zero and align the center of the test format in exact coincidence with the indicator mark.

5.3.5 Set the Projection Lamp Voltage control to NORM, the Scan Time control to zero and the slit control to the narrowest slit width. Make two exposures of the test negative.

5.3.6 Remove the test film from the platen and make a series of esposure control prints with the following combination of exposure control combinations:

PROJECTION LAMP VOLTAGE CONTROL	SCAN TIME CONTROL	SLIT WIDTH
NORM	zero	Narrowest
NORM	50	Narrowest
NORM	100	Narrowest
NORM	100	Widest
NORM	50	Widest
NORM	zero	Widest
HIGH	zero	Widest
HIGH	50	Widest
HIGH	100	Widest
HIGH	100	Narrowest
HIGH	50	Narrowest
HIGH	zero	Narrowest

Keep a written record of the exposure combinations referenced to the copy frame number.

5.3.7 Remove the exposed film from the instrument and process it in accordance with standard technique.

5.4 Test Data

Examine the processed film and record the results in accordance with the following:

5.4.1 Resolution

Use the microscope to read the resolution targets on both test copies. Record the readings in l/mm on a data format similar to the test pattern, placing the resolution figures at their approximate location on the input format.

Resolution minimums should be:

80 l/mm at center

50 l/mm halfway toward each end

40 l/mm at each end

5.4.2 Geometry

Measure the grid squares on the test copies. Record the dimension and variations between the largest and smallest square on each format.

5.4.3 Evenesscof Exposure

Use the densitometer to evaluate each of the exposure control test frames.

Record the variation of density between center and ends of each of the frames.

Variation over any frame should not exceed 10%.

Record the overall density of each of the frames and reference this to the exposure control combination of that frame.

5.5 Results of Photographic Tests

The results of the photographic tests shall be analyzed and evaluated in terms of photographic capabilities of the Gamma I instrument.

VI PHOTOGRAMMETRIC AND DISTORTION CHARACTERISTICS TEST

6.1 Objectives

A complete photogrammetric analysis of the Gamma I output image is necessary for a determination of the instrument's geometric properties. The basis for this analysis is a mathematical comparison of the actual output-image geometry and the theoretically determined output-image geometry, for a given set of optical and mechanical rectifier parameters. The given parameters would originate from a hypothetical flight situation.

6.1 (cont'd)

It is desired that no point in the projected (transformed) image shall be displaced more than 0,010" from the theoretically determined position of that point.

6.1.1 Possible Origin of Instrument Geometric Errors

The following sources of geometric error in a panoramic rectifier of the scanning type should be considered:

6.1.1.1 Optical

6.1.1.1.1 Lens distortion influence across the film width

In any slit-imaging or projection, the optical field of the lens is used along the length of the slit. If radial optical distortion exists in the lens the zones of distortion will produce elements of varying scale across the film.

6.1.1.1.2 Lens distortion influence along the length of the film:

Because the object conjugate (distance from lens to easel) is continually changing during the scanning re-projection, the field of the lens is employed to provide the correct image conjugate (distance from lens to negative) for proper focusing. If radial distortion exists throughout the field of the lens, the scale along the scan will also be varying and will result in incorrect scale along the length of the output image. This scale change can be determined along the image centerline. A complex scale change would occur in the image where different magnitudes of radial distortion affects both dimensions. This is the case in tipped panoramic image re-projection.

6.1.1.1.3 Positioning of the lens with respect to the negative surface and the easel:

The setting of image and object conjugates other than those determined for the rectification scale will result in an actual/theoretical scale difference. These settings are partly determined by the correct focusing of the system, and therefore, if the final lens has an effective focal length other than that used in the original calculations of the shapes and positions of the rectifier components an error will be inherent.

If the lens is rotating about the incorrect (or an eccentric) point, a combined error in focus and scale variation will occur. The focus error can be corrected by the shape of the focusing cam, but the scale variation will remain. Again, this error will be intermixed with radial distortion and earth curvature.

6.1.1.2 Mechanical

6.1.1.2.1 Irregular travel of the illuminating slit will produce photographic banding, but should not influence the image geometry.

6.1.1.2.2 Any physical movement of the negative either across or along the scan during exposure of the complete image will result in geometric errors. These movements could be caused by:

a. side-slip of the film within the guide rails

b. longitudinal film movement due to scanning force or friction

c. irregular movement between slit rollers and film

d. any stretching of the film from incorrect tension or mechanical scanning

6.1.1.2.3 Any physical bulging or twisting of the copy film and/or easel due to easel deformations, irregular vacuum, and copy film transport will produce geometric errors.

6.1.1.3 General

The most obvious sources of geometric error would be the incorrect or inaccurate settings of the rectifier freedoms and orientation values. These would also include incorrect positioning of the negative and the incorrect setting of the easel curvature value.

6.2 Test Equipment

The following equipment items are required for the performance of the elements of this test:

6.2.1 Master Square Grid (with one centimeter line interval)

The master square grid is to be a high quality negative image on an extremely stable film base. The base should be 70mm roll film sufficiently long (approx. 10') to reach from the supply spool to the takeup spool of the input system. The grid image itself should also be sufficiently large to fill the entire input format, including the additional ten degrees of roll coverage (approx. 36"). The use of a square master grid is preferred for the following reasons.

6.2.1.1 An existing glass grid of the standard one-centimeter line interval may be used.

6.2.1.2 The grid in many cases has been, or can readily be, calibrated on a high precision measuring instrument.

6.2.1.3 The master grid line thickness is uniform and in the projected image it will be magnified at the same ratio as the transformed grid square. This will facilitate the measurement of the actual image output as far as selection of a representative corner coordinate is concerned.

6.2.1.4 The master grid can be used for any number of instrument settings where the only change required is in the projective geometry computer program.

As previously noted, the input grid must be exposed on an extremely stable base film. Since the film grid will be calibrated just prior to use, this stability requirement is necessary to resist only the slight mechanical tensions involved in handling the film and any minor changes in operating environment after calibration. The stability requirements imposed on the output film are somewhat more critical. In this case, the film must be as insensitive as possible to the entire processing procedure in addition to the factors mentioned above.

To obtain the greatest possible stability, films having polyestar bases will be used for these geometric tests in preference to the acetate film used in the resolution tests. Two such possibilities, designated as 2427 and 4427, have 4 and 7 mil estar bases, respectively. These films are suggested because their photographic characteristics are very similar to that of the 5427 and, therefore, no changes in exposure should be necessary between these tests and the resolution tests.

6.2.2. Measuring Instrument

The measuring instrument will be used both for calibrating the input grid and for measuring the much larger output grid. It will require, therefore, a precision compatible with errors below the performance requirements (at original negative scale) while at the same time having axes as long as possible in order to measure the output in as few steps as possible. Several possibilities are the large one meter coordinatographs or the smaller, more accurate, eighteen inch comparators. In any event, it is desirable to have automatic digital readout from the instrument in the form of punch cards or tape for immediate use with available computer facilities.

6.2.3 Computer Facilities and Software

The basic computer programs required for the analysis of the output grid measurements include; the projective realationship of given points on the input negative (grid intersections) to their theoretical image positions on the easel, and a conformed least square transformation of the actual measured output grid to this theoretically projected grid. From this latter transformation step, the residuals or positional errors at each point are determined. The pattern of these residuals will in turn indicate the rectifier setting or settings which are in error. The determination of errors in the rectifier setting can be made either analytically within the computer or by simpler graphic methods. Analytical solutions will require more extensive programming, while a graphic solution can be performed with an in-line

6.2.3 (cont'd.)

plotter for displaying the residuals. Any or all of these steps can be easily handled by most digital equipment. The choice of computer facilities will be based, therefore, more on availability rather than capability.

6.3 Test Procedures

6.3.1 Position the master grid in the negative platen in the same manner as for an operational negative. Align the center grid intersection with the roll vernier at zero scan nadir angle. With a grid long enough to cover the entire input format including the ten degrees of roll coverage, it will not be necessary to shift the grid to simulate a roll condition.

6.3.2 Expose the mater grid, label and process the output film in the same manner as for operational material. Standardize these procedures to maintain consistency in the results. Although the output film is quite stable, experience will show whether steps need be taken to control shrinkages of this material.

6.3.3 Make exposures of the master grid with various combinations of rectifier settings. The parameters or settings will be tested both individually and in combination at their respective minimum, means, and maximums. Make a set of exposures while consistantly introducing each setting in the same direction, i.e., minimum to maximum; then, repeat the procedure with a reversal in the order and direction of each setting (maximum to minimum). Keep an exact record of the sequence in which the exposures are made and the rectifier settings for each exposure.

6.3.4 Personnel Utilization

The entire performance test, from the initial photography through mensuration and computer analysis, will be conducted under the direction of a photogrammetric engineer or the equivalent. Although this engineer will be supported in the performance of each task by a qualified technician or junior engineer, he must have a complete understanding of all phases of the operation. Of major importance is this engineer's understanding of the projective geometry involved and the deformations resulting from given projective errors.

The technician who will perform the actual photographic tasks must be completely knowledgeable of the equipment operation and generally familiar with the intent or goal of the performance tests. Ideally, this would be the same individual that conducts the photographic performance tests. Additional support will be provided by a technician who is completely familiar with the mensuration equipment to be utilized.

The final analysis of the test material by the responsible engineer will be performed with the aid of available computer facilities. The equipment operator's needs to conduct this analysis are considered a part of the computer facility and not a personnel requirement as such.

6.4 Test Data

6.4.1 Measure both the master grid and the output grids. Beeause of the scale difference between input and output, the former must necessarily be measured more accurately. In either case, however, the mensuration equipment will most probably not be able to handle the entire film at once. In this event, measure the films a section at a time with sufficient overlap to ensure a reliable joining of adjacent sections through least square conformed transformations.

6.4.2 Compute the coordinates of the grid intersections on the output film from the master grid measurements and the rectifier settings for each exposure. The geometric relations required are very similar in part to those used in the rectifier design analysis. One example set of relations is attached.

6.4.2.1 Example

Figures 2 through 6 illustrate some of the possible image deformations which can result from incorrect mechanical settings and/or optical mechanical distortions inherent in the rectifier components: A graphical comparison of the theoretical and actual transformed images will provide a composite illustration of the errors at their true scale, therefore the computer comparison will be used to provide composite residuals which will then be plotted at an exaggerated scale for graphical deformation analysis and for the determination of the specified fit.

The analytical least-squares adjustment will result in transformation coefficients showing the magnitudes of errors of the various orders anticipated in the transformation.

6.4.2.1 Example (cont.)

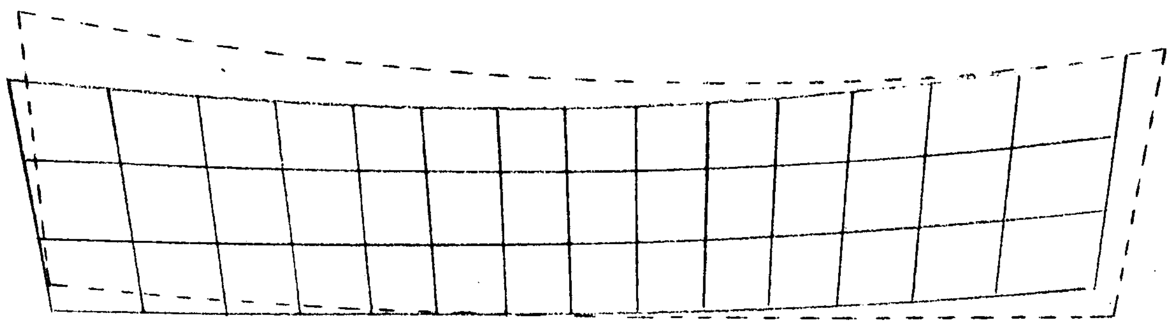

FIGURE 2

Figure 2 illustrates the basic first-order effects of X and Y translation, scale, and rotation: These graph fitting errors will be corrected for by a least squares conformal transformation of the type:

$$Y = ay - bx + Cy$$

$$X = by + ax + Cx$$

If the X and Y scales should be somewhat differential, they can be treated separately as follows:

$$\Delta y = b_o + b_1 + b_2 y$$

$$\Delta x = a_o + a_1 + a_2 y$$

The magnitude of the derived coefficients $a_1 x$ and $b_2 y$ will indicate the overall variation in scale of the two dimensions.

6.4.2.1 Example (cont.)

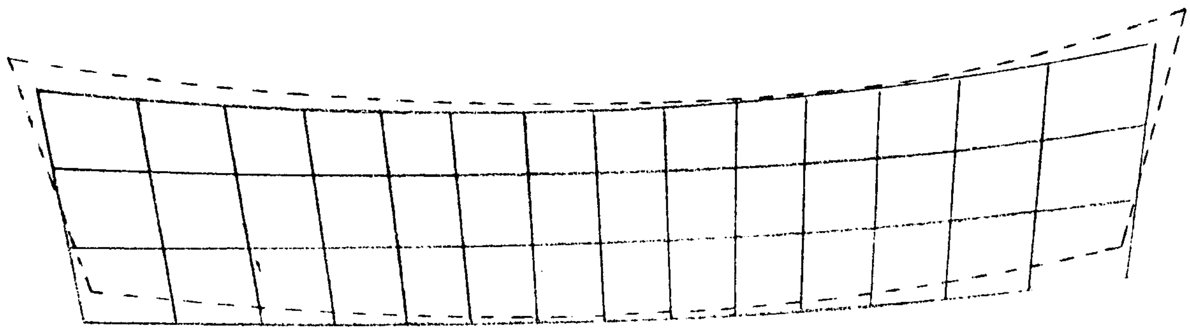

FIGURE 3

Figure 3 illustrates the effect of a tip (φ) error caused by an incorrect instrument setting or a component alignment error. This can be physically corrected for after analysis. An example transformation term would be:

$$\Delta x = a_3x^2$$

$$\Delta y = b_3xy$$

6.4.2.1 Example (cont.)

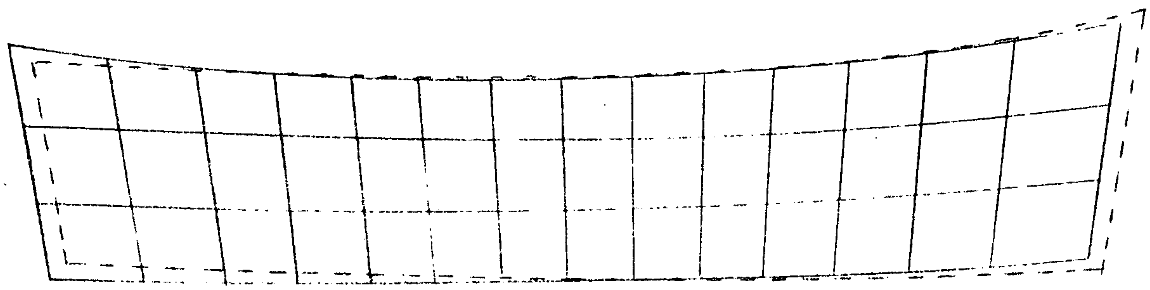

FIGURE 4

Figure 4 illustrates the effect of a tilt (ω) error which could be caused by incorrect negative (nadir) alignment and/or easel tilting about the easel center-line parallel to the scan slit. The sensitivity of "nadir" alignment can be computed and related to the fitting tolerance. If the optimum focusing of the projection lens is equal for all angles off of the optical axis the easel tilt error will not occur. Should the focus vary from side to side, the easel must be zeroed photogrammetrically and the focusing cam modified accordingly. The determination of the magnitude of this error could be represented by the transformation terms:

$$\Delta x = a_4 xy$$

$$\Delta y = b_4 y^2$$

6.4.2.1 Example (cont.)

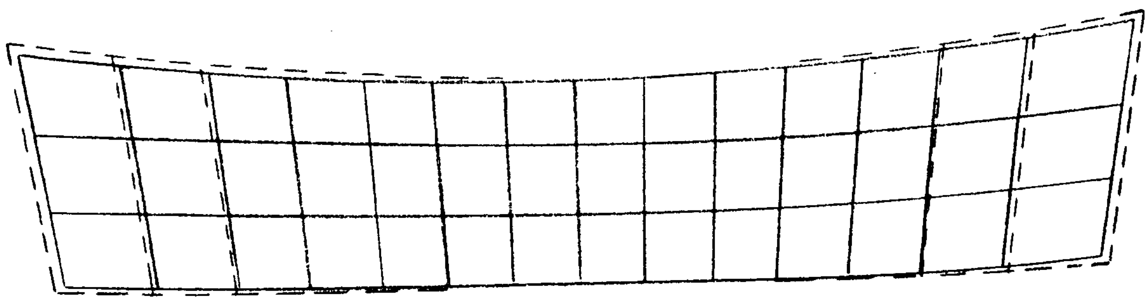

FIGURE 5

Figure 5 illustrates the effect of a physical easel curvature which differs from the theoretical easel curvature. It will have a second-order scale effect symmetrical about the easel axis (zero scan). The illustration shows the effect of an actual radius which is greater than the theoretical input. This error can be physically corrected for with adjusted values of the easel radius dials.

6.4.2.1 Example (cont.)

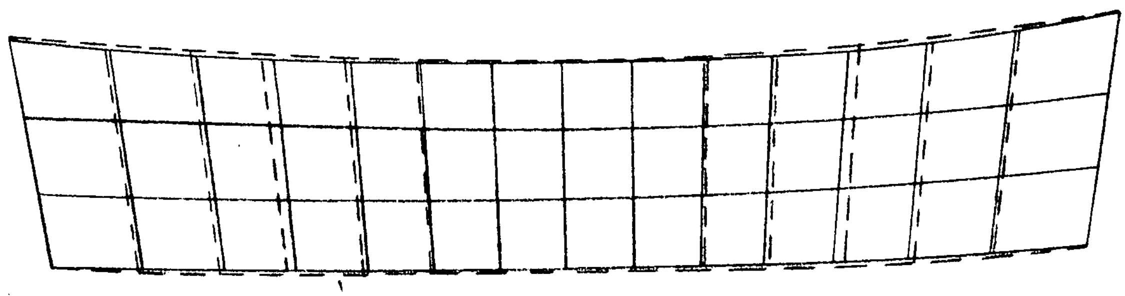

FIGURE 6

Figure 6 shows the effect of a positive lens distortion radially symmetrical about the optical axis and rectifier scan axis but returning to zero radial distortion at the maximum scan angles. This is one of many distortion possibilities which might be considered. The Gamma I lens is specially designed for low distortion values but with precise image calibration; certain systematic optical distortions can be determined.

6.4.3 Transform the measured coordinates of the grid intersections on the output film through the method of least squares to the computed easel coordinates for the same rectifier settings.

Analyze the pattern of the discrepencies or residuals between these two systems.

6.4.4 Perform the analysis of the rectification errors either analytically or graphically. In the analytical technique, the computer would compute through a differential form of the projection relations the error in the setting or settings which produce the given pattern of residuals.

Similar information can be deducted by the operator from graphical plots of the residuals. In this latter case, a knowledge of the residual pattern related to an error in each parameter is necessary. The computer should indicate the magnitude of the largest residual and also the standard error.

6.4.5 Use the following information as a guide for comparing the measured grid projection to a theoretical grid:

The Gamma I optical projection is from a cylinder of radius (f) to a tipped cylinder of radius (R) in map scale. The easel cylinder represents a portion of a sphere with radius (R). Because of the very short ground image elements in one direction i.e., line-of-flight, and by the use of an easel tip value in the line-of-flight which is other than the original scanning tip, the sphere is closely represented by a cylindrical section. Physically, of course, the duplicating film can be transported on, and held to a cylindrical surface.

Given:
Φ = tip of optical axis from vertical at center of scan
H = vertical height above sphere
R = radius of sphere
f = focal length
m = scale factor

Measured:
x_i, y_i = image coordinates in system with x - axis opposite the direction of tip, y - axis parallel to scan, and origin (x_o, y_o) in center format.

Find:
X_i, Y_i = coordinates on sphere in system with X - axis in direction of tip, Y - axis normal to this, and origin at nadir

Compute:
1) angular image position from axis measured in direction of tip

$$\varphi = \tan^{-1} \frac{x - x_o}{f}$$

2) angle of image projection from vertical in direction of tip

$$\Phi' = \Phi + \varphi$$

3) angle of image projection with respect to tangent plane (cylinder)

$$t = \sin^{-1}\left(\frac{R + H}{R} \sin \Phi'\right)$$

4) geocentric angle for tilt

$$\delta = t - \Phi'$$

5) slope distance to sphere

$$S = \frac{H \cos \delta/2}{\cos (t - \delta/2)}$$

6) radius of circular section

$$\rho = R \cos t$$

7) scan angle

$$\alpha = \frac{y - y_o}{f}$$

8) central angle of circular section for scan

$$\delta' = \sin^{-1} \left(\frac{\rho + s}{\rho} \sin\alpha\right) - \alpha$$

9)

$$\beta = \tan^{-1} \left(\frac{\tan t}{\cos \delta'}\right)$$

10) geocentric angle for X component of scan

$$\delta'' = \beta - t$$

11) X coordinate at given scale

$$X = Rm (\delta + \delta'')$$

12) geocentric angle for Y

$$\delta''' = \sin^{-1}\left(\frac{\rho}{R} \sin\delta'\right)$$

13) Y coordinate at given scale

$$Y = Rm\, \delta'''$$

6.4.5 (cont.)

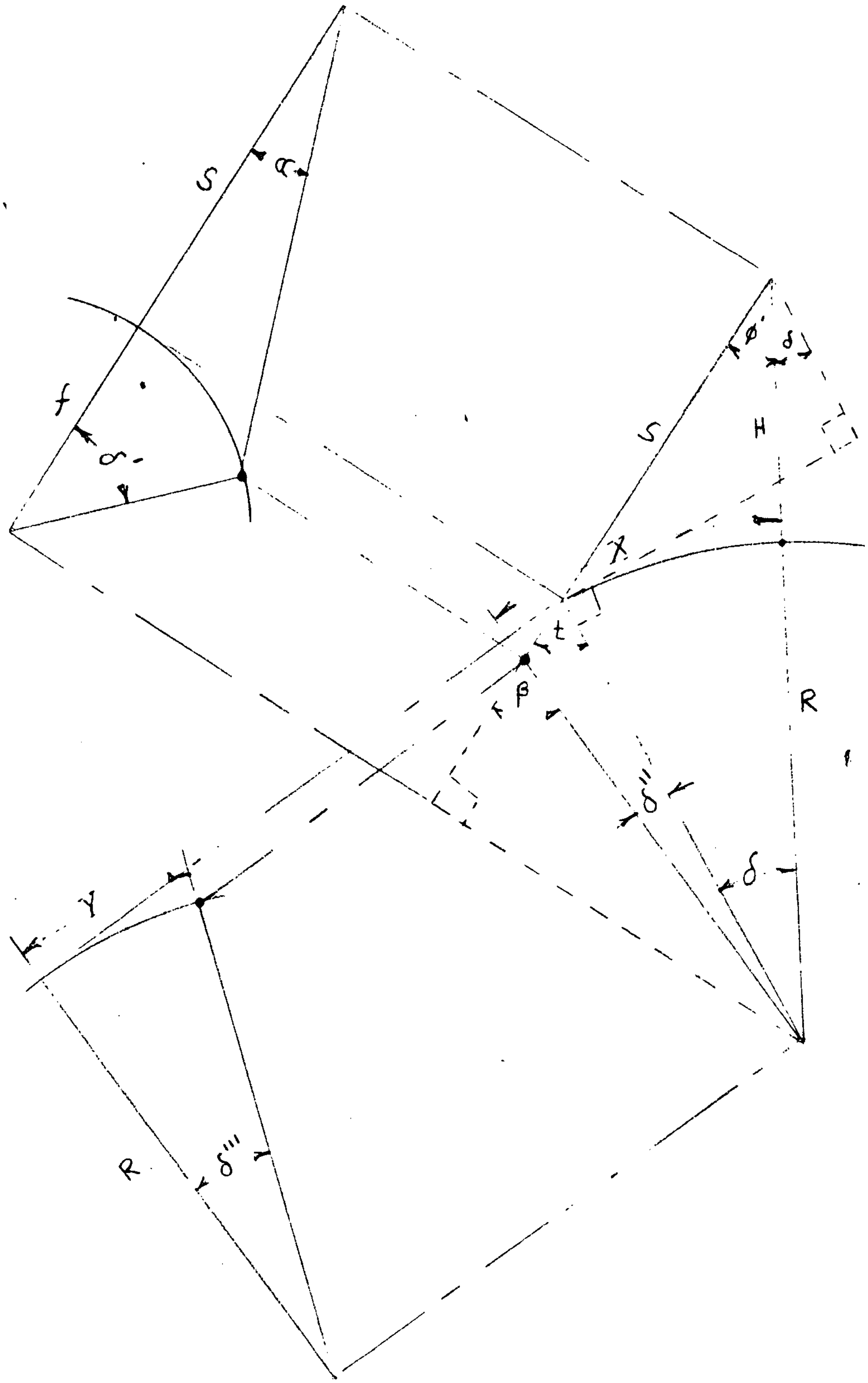

FIGURE 7

6.5 Results of the Photogrammetric and Distortion Characteristics Test

The results of this test will be analyzed and evaluated in terms of the total rectifying capability of the instrument.

6.6 Characteristics

The individual characteristics of each instrument tested will be evaluated, defined, and compiled and recorded as correction factors to be applied to the outputs of the instruments during operation.

VII HUMAN ENGINEERING EVALUATION

7.1 Objectives

To determine the effectiveness of design and construction by minimizing factors unfavorable to the instrument operator.

7.2 Procedure

During performance of the test procedures, specific notes will be itemized for the following features.

7.2.1 Controls - Check list	Yes	No	N/A
1. The controls require as few movements as possible.			
2. Successive control movements are interrelated (one passes into another).			
3. Controls used in rapid sequence have a uniform direction of motion.			
4. Activation of control does not obscure visual display.			
5. The relationship between control and associated function is unmistakable.			
6. Control movements to increase magnitude are forward for linear motion or clockwise for rotary controls.			
7. Placement of controls is convenient for right hand operation.			
8. Width of numerals is 3/5 of height.			
9. Legend is unique to its function.			
10. Pushbuttons are at least ½ inch in diameter.			
11. Control resistance is 5 - 20 ounces.			
12. Audible clicks for control operation.			
13. Knob diameters 3/8 - 4 inches; depths 1/2 - 1 inch.			

7.2.1 Controls - Check list (cont'd) — Yes No N/A

14. Levers for finger grasp are ½ - 1 inch; for hand grasp, 1½ - 3 inches.

15. Indicator lights are flush with panel.

16. Counters read from left to right.

7.2.2 Handles - Check List — Yes No N/A

1. Handles are provided on large removable components.

2. Weight to move under 25 pounds, handle diameter ¼ - ½ inch; over 25 pounds, ½ - 3/4 inch; clearence 2 inches for both.

7.2.3 Ventilation Louvres - Check List — Yes No N/A

1. Louvres are sufficiently small to prevent insertion of test probes, screwdrivers, or other tools.

7.2.4 Operator Safety - Check List — Yes No N/A

1. Conductors are bound into cables and held by lacing twine.

2. Long internal conductors are secured to chassis and framework by cable clamps.

3. Cables are sufficiently long to allow drawer movement without breaking connections.

4. Grommets are used to prevent chafing where cables are routed through the equipment.

5. Individual cables are color coded where necessary.

6. One-turn or quick-disconnect plugs are used.

7. Plugs or connectors have aligning pins.

8. Socket rather than plug contacts are "hot".

9. Fuses and/or circuit breakers are located to be readily seen and easily replaced or reset.

7.2.5 Tools - Check List	Yes	No	N/A
1. Variety of tools is held to a minimum.			
2. Tools are dull finished to preclude glare.			
3. Speed and rachet tools are provided where necessary.			

VIII ORGANIZATION OF TESTS

8.1 Location

The Engineer Test shall be performed at a location designated by the contracting agency.

8.2 Supervision

The performance of the tests shall be supervised by GIMRADA or GIMRADA designated personnel.

8.3 Personnel

A project engineer and a technician, skilled in each phase of operation, are required. A standby electrical technician will be required for electrical repairs.

8.4 Training

Key test personnel will be trained by [redacted] during the Endurance and STAT Acceptance test periods.

8.5 Period of Test

It is estimated that a period of 8 weeks will be required to perform all test elements.

This estimate is based on the assumption that no major breakdown will occur during the test period. In the event that an unforseen breakdown does occur, the test period will be extended by the amount of time necessary to perform remedial procedures.

IX SUPPORT

9.1 Facilities

Facilities for performing the Engineer Test will be provided by the contracting agency and shall conform in general to the following specifications:

9.1.1 Space

The test area shall be a single room 20' long x 10' wide with an 8' high ceiling. The floor must be capable of supporting a minimum of 1600 pounds, which weight consists of the instrument and the test personnel.

9.1.2 Environment

<u>9.1.2.1 Temperature:</u> 70 degrees F $\pm$ 5 degrees.

<u>9.1.2.2 Humidity:</u> 50% RH $\pm$ 5%.

<u>9.1.2.3 Illumination:</u> Darkroom conditions with EK recommended safe-lights for #5427 emulsion.

9.1.3 Electrical Requirements

9.1.311 Voltage: 115 volts, single phase 60 cps ac.

9.1.3.2 Power: 2000 watts

9.1.4 Photographic Facilities

Darkroom facilities will be provided by the contracting agency to process the photography produced during the tests.

9.2 Equipment

The following equipment items will be furnished by the contracting agency for the purpose of performing the Engineer test:

9.2.1 Electrical

Volt-ohm meter Simpson #260 (or equivalent)

9.2.2. Measurement

STAT

Co-ordinatograph or 18" Comparator

9.2.3 Photographic

Densitometer
Binocular Microscope
Processor

9.2.4 Additional Equipment

Computer Facilities, CDC 924, or equivalent.

9.3 Data

No specific data will be required for the performance of these tests.

9.4 Photography

Photographs of the instrument, major components, and important features shall be taken by the test group to document the equipment and the test.

9.4.1 General

The following procedures shall be observed:

9.4.1.1 The item to be photographed shall be prepared so that it will present the best possible appearance and show maximum detail. If these criteria are conflicting, two photographs will be taken, one to satisfy each. Special attention shall be given to cleanliness, exterior finish, replacement or repair of damaged components and the presence of complete equipment.

9.4.1.2 When the presence of personnel is appropriate to a photograph, regular operating personnel in their common work clothes will be photographed. If these personnel are military they will wear full appropriate uniform.

9.4.1.3 Care shall be taken to place the equipment to be photographed in the most advantageous position for lighting and background to give optimum photographic results.

9.4.1.4 Care shall be taken to avoid serious scale distortion effects in the photograph. Some positive scale representation, such as a pencil, a ruler, or a paper clip, shall be provided in each photograph.

9.4.1.5 All the necessary artwork to produce a definitive photographic negative shall be provided.

9.4.2 Overall Photographs

The following six (6) overall photographs shall be taken:

9.4.2.1 Front View

9.4.2.2 Three Quarter View - Left

9.4.2.3 Three Quarter View - Right

9.4.2.4 Rear View

9.4.2.5 Side View - Left

9.4.2.6 Side View - Right

9.4.3 Component Photographs

The following sixteen (16) component photographs shall be taken:

9.4.3.1 Light Source and Cooling System

9.4.3.2 Light Source - Drive and Exposure Control

9.4.3.3 Lens Assembly

9.4.3.4 Scheimpflug Control Assembly

9.4.3.5 Negative Transport Mechanism

9.4.3.6 Negative Transport - Right Reverse Side

9.4.3.7 Negative Transport - Left Reverse Side

9.4.3.8 Roll Control (nadir offset)

9.4.3.9 Projection Easel - Right Side View

9.4.3.10 Projection Easel - Left Side View

9.4.3.11 Tilt Controls

9.4.3.12 Copy Film Transport System

9.4.3.13 Control Panel

9.4.3.14 Control Chassis - Top

9.4.3.15 Control Chassis - Front

9.4.3.16 Control Chassis - Rear

9.5 Equipment Repairs and Modification

As required, the equipment shall be repaired and modified during this test by the test personnel. The project engineer shall be notified of any malfunction that cannot be corrected by the personnel assigned to the task.

X TEST RESULTS AND THEIR EVALUATION

10.1 Objectives

The objectives of the Engineer Test are to obtain conclusive results with which to evaluate the performance of the Gamma I Rectifying Printer, and to obtain data for use in improving the design and enhancing the operational capabilities.

10.2 Form of Results

All tests and their resulting data will be recorded in Laboratory Notebooks for permanent record.

10.3 Evaluation

Upon completion of all test elements, evaluations will be performed for all principal features, and an overall evaluation will be made.

XI TEST REPORT

A complete Engineer Test Report will be prepared in accordance with GIMRADA defined procedures and specifications.

XII CONCLUSIONS

The test report will contain conclusions based on an analysis of the test results and an evaluation of the same.

XIII RECOMMENDATIONS

Cognizant test personnel shall make recommendations (as a result of test findings) for modifications and design changes which would improve the operation, enhance the photogrammetric capabilities, and/or simplify the operating techniques. These recommendations shall be included in the Test Report.

XIV SCHEDULE

14.1 Objective

In order to maintain a continuous test program, a tentative schedule of personnel requirements and task periods will be established.

14.2 Procedure

The general format of the schedule will be as follows:

TASK	PERSONNEL CATEGORY	NUMBER REQUIRED	TIME REQUIRED
Inspection and Preliminary Acceptance			
Installation			
Training			
Endurance Test			
Instrumental Test			
Photographic Test			
Photogrammetric and Distortion Characteristics Test			
Preparation of Test Report			
Conclusions and Recommendations			